

Report to NOAA Fisheries Southeast Fisheries Science Center

for contract work on:

Development of a two-sex, population-specific model for Atlantic loggerheads

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Overview

In the 30 years since Nat Frazer first synthesized demographic information on Atlantic loggerhead sea turtles (*Caretta caretta*), new information has been collected by a number of NOAA Fisheries and academic researchers on sex ratios, population distribution, life history and interactions with fisheries. Some of these data are being incorporated into recovery planning by the new Loggerhead Recovery Team, and was used to update life cycle models (NMFS 2001). However, there has not yet been an attempt to construct new models that include the specific dynamics and interactions of the primary loggerhead subgroups, as defined by the Turtle Expert Working Group (2000). There are number of critical questions to address, including: 1) the relative contribution of the Northern nesting subpopulation to eastern U.S. nesting stocks, primarily through the production of males, 2) the distribution of the Northern and South Florida genetic stocks in pelagic and nearshore environments, which affects their mortality rates from fisheries bycatch, and 3) the potential impacts of current and future management activities by NOAA Fisheries on the genetic stocks and the population as a whole.

The first step will be to design and heuristically test a model or series of models to explore these questions by synthesizing new information on age, growth, population size and distribution of genetic stocks.

Objectives

1. To develop a stage- and age-structured, 2-sex demographic model.
2. To run sensitivity analyses on the model and identify critical uncertainties
3. To synthesize new information on loggerhead sex ratio and growth from the 2002-2003 Duke University/Florida Atlantic University hatchling study, producing a preliminary geographic distribution of abundance and sex ratio distributions for loggerhead hatchling production on the eastern coast of the U.S. Cooperators are J. Wyneken (FAU), Larry Crowder (Duke), Melissa Snover (PMEL, UC Santa Cruz).

Methods: Population model construction

The data generated by the sex ratio analyses is the key component of new population models to assess the importance of multiple stressors on loggerhead turtle populations. The PIs have met and discussed alternative model structures and approaches for analysis with Dr. Selina Heppell of Oregon State University (under contract with the SE Fisheries Science Center of NOAA Fisheries). The models will build on those developed by Melissa Snover, Larry Crowder and Sheryan Epperly (NMFS 2002) and discussed in Heppell et al. (2003). They will include both sexes and population structure in the form of stages that occur in different habitats. The goal of the modeling exercise is to determine the relative contributions of Northern and Southern stocks to population growth as a whole and to determine how stressors in particular environments (beaches, open sea, nearshore) may affect population dynamics.

Model 1: Deterministic with fixed stage durations

This model utilizes 4 age-structured submodels: Northern males, Northern Females, Southern Males, Southern Females. The 4 submodels run in parallel, allowing calculation of the

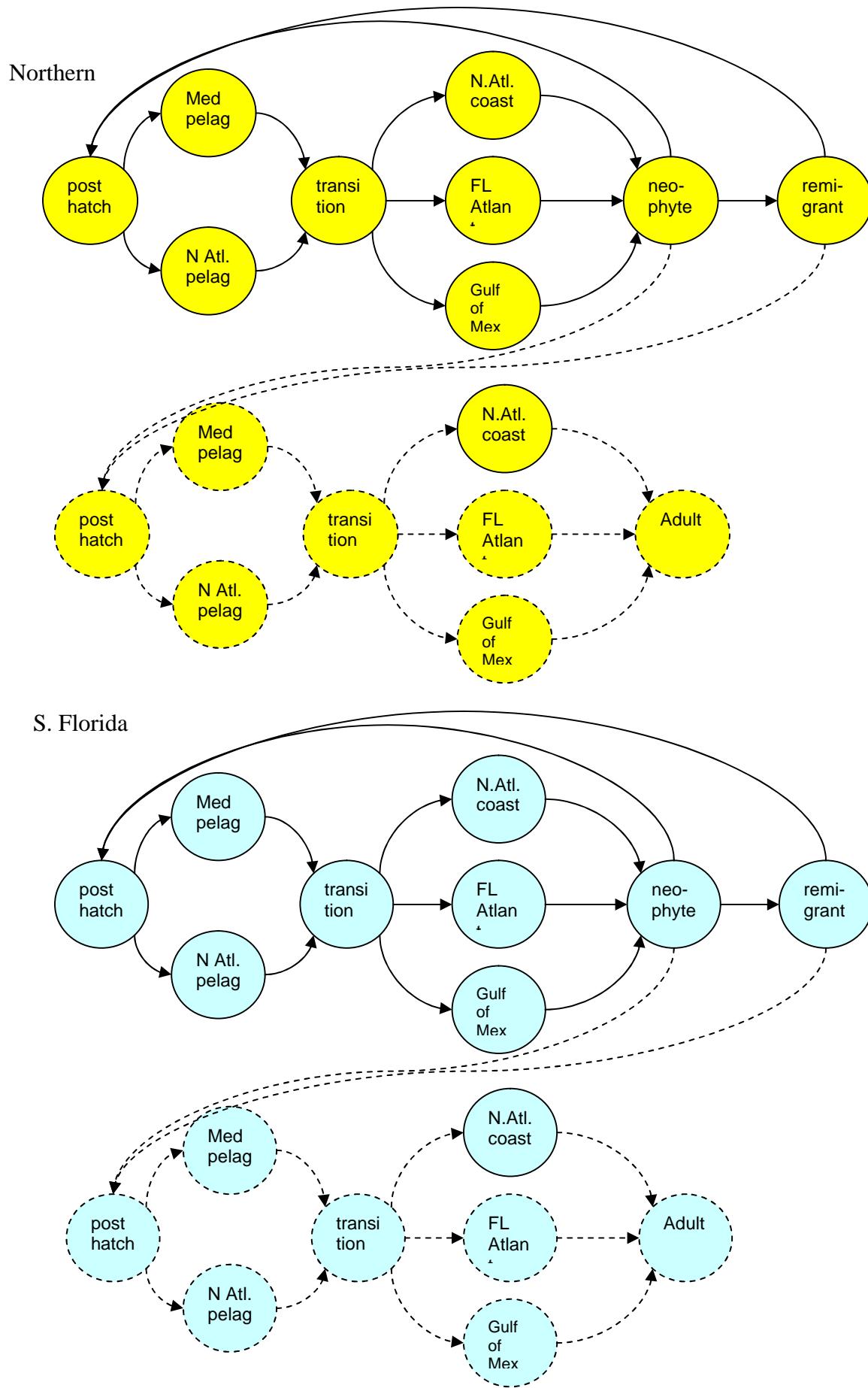
proportion of each stock and sex in each stage. Stages represent habitats and/or life stages, and most have multiple age classes in a stage. For this version, stage durations are fixed and the models are deterministic. Reproduction is dependent on the proportion of males in the population. Figure 1 shows the conceptual model with the 4 components. Each circle represents a stage with a different number of age classes. Arrows represent reproduction or transition probabilities; dashed lines are males, solid lines are females. The number of years in a stage and survival rates can be specific for male vs. female, Northern vs. Southern, although we are unlikely to have data to support differential mortality. Reproduction occurs only in the 2 female submodels, but can be a function of the number of males from the North and South.

The model was constructed with Mathcad 2001 (pages 5-16). Dummy parameters have been installed to allow the generation of the matrices and initial sensitivity analysis (elasticity of the deterministic growth rate to changes in stage-specific survival).

Parameterization of these relatively simple models will require substantial effort. Data collected from the EPA study (Wyneken and Crowder, analysis in prep) will go into the measures of fertility: the number of male and female hatchlings produced in the North and South each year. Post-hatchling survival will also be subpopulation specific, if data become available in 2004. Growth rates (= stage durations) and survival rates will come from the literature and from in-water survey data obtained from cooperators in Florida and North Carolina. The proportion of turtles migrating to alternative locations (pelagic turtles to the Mediterranean and benthic turtles to the North Atlantic, Florida and Gulf of Mexico) is a difficult problem because there is not enough tagging information to determine the probability of settling in one location vs. another. However, if we make the assumption of equal at-sea survival rates for juvenile males and females from the North and South, we may be able to use genetic and sex ratio information from surveys in each location to reconstruct those probabilities.

Sensitivity analysis will be critical for this model to a) assess the importance of uncertainty in unknown parameters and b) calculate the relative contribution of each location-specific survival rate to overall population growth (elasticity analysis- Caswell 2001). Heppell recommends a combination of individual parameter sensitivity assessment and Monte Carlo approaches to generate distributions of model outputs.

Continued work on this project in 2004 and 2005 will include a simplification of the model to reduce the number of unknown parameters. Specifically, we will eliminate the geographic splits for the pelagic and juvenile benthic life stages, and concentrate more on the effects of variable stage lengths (caused by variable growth rates). Although the simple model will be less unwieldy, it will not allow an assessment of the relative impacts of region-specific management, such as TED effectiveness in the SE Atlantic states vs. the Gulf of Mexico.



Atlantic loggerhead model v. 2.1
Selina Heppell August 2004

ORIGIN ≡ 1

This model utilizes 2 age-structured, 2-sex models: Northern females and males, Southern females and males. Both populations subdivide into different stages that represent regional locations. Survival rates are based on location and are constant for juvenile life stages (male and female, both populations). Survival rates for adult males and females of each population are independent parameters. Growth rates (= stage lengths) can also be specific to each population and sexes within populations. The 2 models run in parallel, allowing calculation of the proportion of each stock and sex in each stage.

Juvenile survival rates

$$\begin{array}{ll} \text{post-hatchling (age 1-2)} & \left(\begin{array}{l} .5 \\ .72 \end{array} \right) \\ \text{Mediterranean pelagic} & \left(\begin{array}{l} .8 \\ .85 \end{array} \right) \\ \text{Atlantic pelagic} & \left(\begin{array}{l} .9 \\ .9 \end{array} \right) \\ \text{Transition pelagic} & \left(\begin{array}{l} .9 \\ .9 \end{array} \right) \\ \text{Mid Atlantic benthic} & \left(\begin{array}{l} .9 \\ .9 \end{array} \right) \\ \text{Florida benthic} & \left(\begin{array}{l} .9 \\ .9 \end{array} \right) \\ \text{Gulf benthic} & \left(\begin{array}{l} .9 \\ .9 \end{array} \right) \end{array}$$

1. Northern nesting subpopulation primary sex ratio: pSRN := 0.7

$$\begin{aligned} \text{proportion moving to "split" stages} & \quad \text{propMed1} := 0.2 \\ & \quad \text{propNA1} := 1 - \text{propMed1} \\ & \quad \text{propFL1} := 0.2 \\ & \quad \text{propG1} := 0.1 \\ & \quad \text{propN1} := 1 - \text{propFL1} - \text{propG1} \end{aligned}$$

female stage lengths:

$$T := \left(\begin{array}{l} 1 \\ 3 \\ 4 \\ 2 \\ 15 \\ 12 \\ 12 \\ 4 \end{array} \right) \quad \begin{array}{l} \text{post-hatchling} \\ \text{Mediterranean pelagic} \\ \text{Atlantic pelagic} \\ \text{Transition pelagic} \\ \text{Mid Atlantic benthic} \\ \text{Florida benthic} \\ \text{Gulf benthic} \\ \text{Adult (1st remigration interval)} \end{array}$$

male stage lengths:

$$TNm := \left(\begin{array}{l} 1 \\ 3 \\ 4 \\ 2 \\ 12 \\ 8 \\ 8 \end{array} \right)$$

Northern adult female survival Nadf := 0.93

Northern adult male survival Nadm := 0.93

reproduction - neophyte females

$$fneo := \left(\begin{array}{l} pSRN \\ 90 \\ 3 \\ 0.6 \\ T_8 \\ .25 \end{array} \right) \quad \begin{array}{l} \text{sex ratio (proportion female)} \\ \text{eggs per nest} \\ \text{nests per female} \\ \text{nest survival} \\ \text{remigration} \\ \text{hatching survival to age 1} \end{array}$$

$$FN1 := ((fneo_1 \cdot fneo_2 \cdot fneo_3 \cdot fneo_4) \cdot fneo_5)$$

$$FN1 = 28.35$$

reproduction - experienced females

$$f2 := \left(\begin{array}{l} pSRN \\ 110 \\ 4 \\ 0.6 \\ 4 \\ .25 \end{array} \right) \quad FN2 := \frac{f2_1 \cdot f2_2 \cdot f2_3 \cdot f2_4}{f2_5} \cdot f2_6$$

$$FN2 = 11.55$$

range variables:
 $tph := 1..T_1$
 $tmed := T_1 + 1..T_1 + T_2$
 $tap := T_1 + T_2 + 1..T_1 + T_2 + T_3$
 $tp := T_1 + T_2 + T_3 + 1..T_1 + T_2 + T_3 + T_4$
 $q := 1..7$
 $adN1 := \sum_q T_q + 1$
 $i := 1..adN2$
 matrix construction
 $M1_{tph+1, tph} := js_1$
 $M1_{(T_1+1, T_1)} := js_1 \cdot propMed1$
 $M1_{(T_1+T_2+1), T_1} := js_1 \cdot (1 - propMed1)$
 $M1_{tmed+1, tmed} := js_2$
 $M1_{i, T_1+T_2} := 0$
 $M1_{(T_1+T_2+T_3+1), T_1+T_2} := js_2$
 $M1_{tap+1, tap} := js_3$
 $M1_{tp+1, tp} := js_4$
 $M1_{(T_1+T_2+T_3+T_4+1), T_1+T_2+T_3+T_4} := js_4 \cdot propN1$
 $M1_{(T_1+T_2+T_3+T_4+T_5+1), T_1+T_2+T_3+T_4} := js_4 \cdot propFL1$
 $M1_{(T_1+T_2+T_3+T_4+T_5+T_6+1), T_1+T_2+T_3+T_4} := js_4 \cdot propG1$
 $M1_{tN+1, tN} := js_5$
 $M1_{i, T_1+T_2+T_3+T_4+T_5} := 0$
 $M1_{adN1, T_1+T_2+T_3+T_4+T_5} := js_5$
 $M1_{tF+1, tF} := js_6$
 $M1_{i, T_1+T_2+T_3+T_4+T_5+T_6} := 0$
 $M1_{adN1, T_1+T_2+T_3+T_4+T_5+T_6} := js_6$
 $T_1 + T_2 + T_3 + T_4 + T_5 + T_6 = 37$
 $js_6 = 0.9$
 $M1_{tG+1, tG} := js_7$
 $M1_{adN1, adN1-1} := js_7$
 $M1_{tAd+1, tAd} := Nadf$
 $M1_{adN1, adN1} := FN1$
 $M1_{1, adN2} := FN2$
 $M1_{adN2, adN2} := Nadf$
 $adN1 = 50$
 $rows(M1) = 54$
 $cols(M1) = 54$

$tN := T_1 + T_2 + T_3 + T_4 + 1..T_1 + T_2 + T_3 + T_4 + T_5$	$Tph := 1..T_1$
$tF := T_1 + T_2 + T_3 + T_4 + T_5 + 1..T_1 + T_2 + T_3 + T_4 + T_5 + T_6$	$Tmed := 1..T_2$
$tG := T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + 1..T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7$	$Tap := 1..T_3$
$tAd := T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + 1..T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8$	$Tp := 1..T_4$
$TN := 1..T_5$	$TN := 1..T_5$
$TF := 1..T_6$	$TF := 1..T_6$
$TG := 1..T_7$	$TG := 1..T_7$
$adN2 = 54$	$adN2 = 54$

$tF =$	$tAd =$
26	50
27	51
28	52
29	53
30	
31	
32	
33	
34	
35	
36	
37	

$T_8 = 4$

$s = 1\text{ s}$

$\lambda1 := \max(\operatorname{Re}(\operatorname{eigenval}(M1)))$ $\lambda1 = 1.052$

$$w := \frac{\text{eigenv}(M1, \lambda_1)}{\sum \text{eigenv}(M1, \lambda_1)} \quad N := 1000000 \quad v := \frac{\text{eigenv}(M1^T, \lambda_1)}{\text{eigenv}(M1^T, \lambda_1)_1}$$

	1
1	304604.8
2	28964.65
3	19830.44
4	13576.76
5	115858.59
6	88135.27
7	67045.74
8	51002.65
9	48093.67
10	38872.13
11	21993.12
12	18821.78
13	16107.75
14	13785.07
15	11797.31
16	10096.17
17	8640.34
18	7394.43
19	6328.18
20	5415.68
21	4634.76

	1
1	1
2	2.033
3	2.969
4	4.336
5	2.121
6	2.788
7	3.665
8	4.818
9	6.334
10	7.836
11	8.226
12	9.612
13	11.231
14	13.123
15	15.335
16	17.918
17	20.938

j := 1 .. adN2

$$E_{i,j} := \frac{v_i \cdot w_j}{v \cdot w} \cdot \frac{M1_{i,j}}{\lambda_1}$$

$$\sum_i \sum_j E_{i,j} = 1$$

$$w1stage := \begin{bmatrix} \sum_{tph} w_{tph} \\ \sum_{tmmed} (w_{tmmed}) \\ \sum_{tap} (w_{tap}) \\ \sum_{ttip} (w_{tip}) \\ \sum_{tN} (w_{tN}) \\ \sum_{tF} (w_{tF}) \\ \sum_{tG} (w_{tG}) \\ \sum_{tAd} (w_{tAd}) + w_{adN2} \end{bmatrix}$$

qq := 1 .. 8

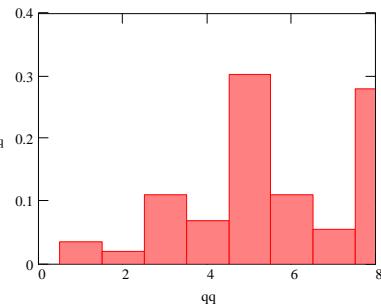
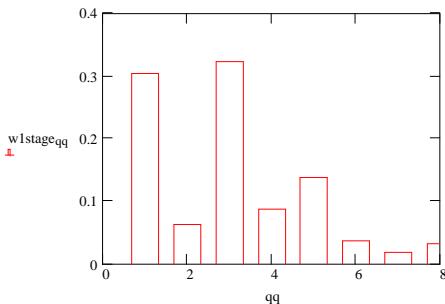
$$\text{Elast1} := \begin{bmatrix} \sum_{tph} \left(\sum_i E_{tph,i} \right) \\ \sum_{tmmed} \left(\sum_i E_{tmmed,i} \right) \\ \sum_{tap} \left(\sum_i E_{tap,i} \right) \\ \sum_{ttip} \left(\sum_i E_{tip,i} \right) \\ \sum_{tN} \left(\sum_i E_{tN,i} \right) \\ \sum_{tF} \left(\sum_i E_{tF,i} \right) \\ \sum_{tG} \left(\sum_i E_{tG,i} \right) \\ \sum_{tAd} \left(\sum_i E_{tAd,i} \right) + E_{adN2, adN2} \end{bmatrix} \quad \text{Elast1} = \begin{bmatrix} 0.034 \\ 0.02 \\ 0.109 \\ 0.068 \\ 0.302 \\ 0.11 \\ 0.055 \\ 0.28 \end{bmatrix}$$

$$tAd = \begin{bmatrix} 50 \\ 51 \\ 52 \\ 53 \end{bmatrix}$$

$$w_{tmmed} = \begin{bmatrix} 0.029 \\ 0.02 \\ 0.014 \end{bmatrix}$$

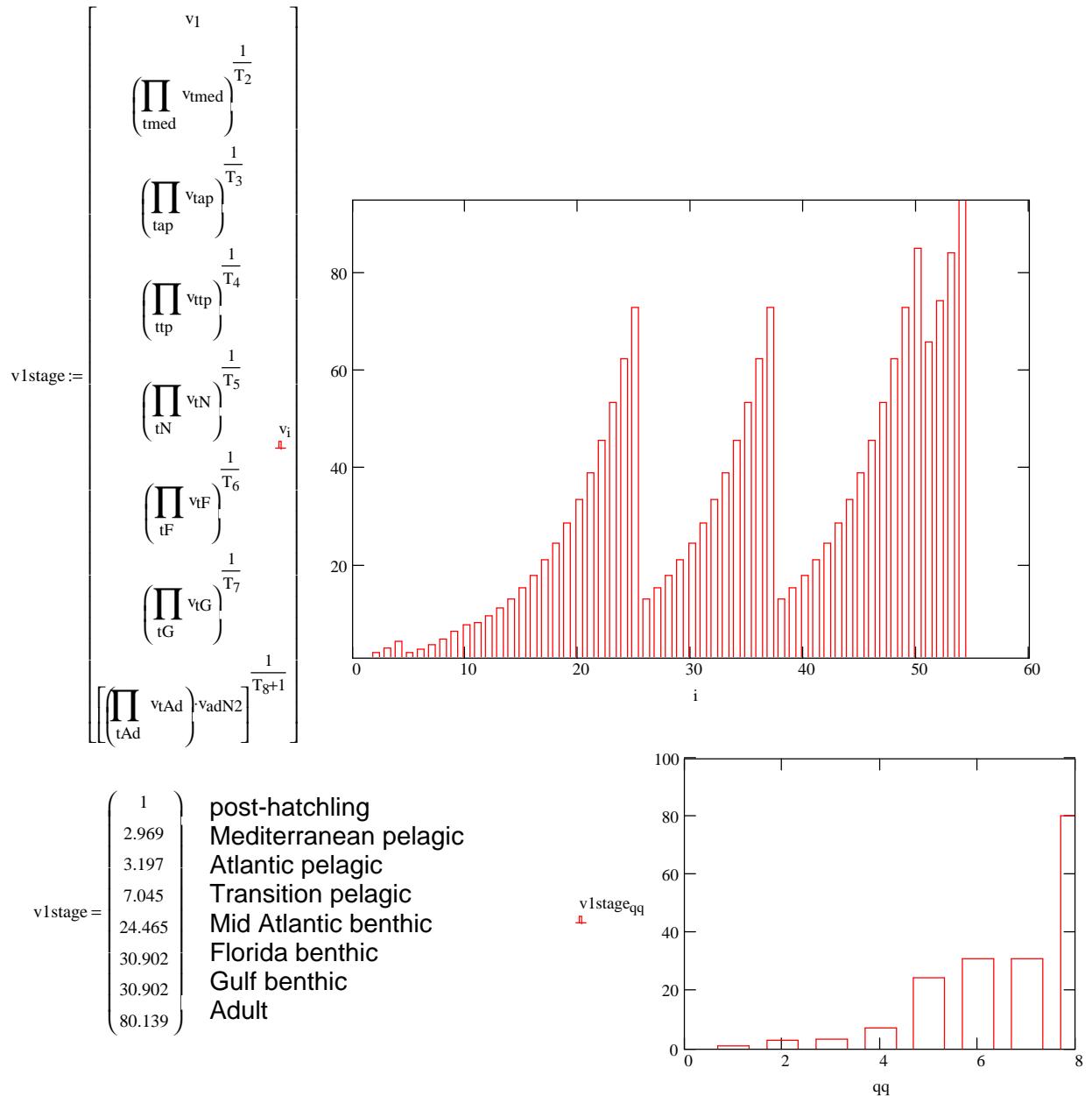
$$w_{tap} = \begin{bmatrix} 0.116 \\ 0.088 \\ 0.067 \\ 0.051 \end{bmatrix}$$

$$\sum_{tmmed} (w_{tmmed}) = 0.062 \quad \sum_{tap} (w_{tap}) = 0.322$$



post-hatching
Mediterranean pelagic
Atlantic pelagic
Transition pelagic
Mid Atlantic benthic
Florida benthic
Gulf benthic
Adult

	1
1	0
2	0.00654
3	0.00
4	0
5	0.02731
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0
32	0
33	0
34	0
35	0



Northern nesting subpopulation - males
 sex ratio: $pSRNm := 1 - pSRN$ $pSRNm = 0.3$
 stage lengths:
 post-hatching
 Mediterranean pelagic
 Atlantic pelagic
 $T := TNm$ Transition pelagic
 Mid Atlantic benthic
 Florida benthic
 Gulf benthic
 proportion moving to "split" stages
 $propMed2 := propMed1$
 $propNA2 := 1 - propMed2$
 $propFL2 := propFL1$
 $propG2 := propG1$
 $propN2 := 1 - propFL2 - propG2$

range variables:
 $tph := 1 .. T_1$ $tN := T_1 + T_2 + T_3 + T_4 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5$ $Tph := 1 .. T_1$
 $tmed := T_1 + 1 .. T_1 + T_2$ $tF := T_1 + T_2 + T_3 + T_4 + T_5 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5 + T_6$ $Tmed := 1 .. T_2$
 $tap := T_1 + T_2 + 1 .. T_1 + T_2 + T_3$ $tG := T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7$ $Tap := 1 .. T_3$
 $tp := T_1 + T_2 + T_3 + 1 .. T_1 + T_2 + T_3 + T_4$ $Tp := 1 .. T_4$
 $q := 1 .. 7$ $TN := 1 .. T_5$
 $ad1 := \sum_q T_q + 1$ $TF := 1 .. T_6$
 $ad1 = 39$ $TG := 1 .. T_7$
 $i := 1 .. ad1$

matrix construction
 $M2_{tph+1, tph} := js1$
 $M2_{(T_1+1, T_1)} := js1 \cdot propMed2$
 $M2_{(T_1+T_2+1), T_1} := js1 \cdot (1 - propMed2)$
 $M2_{tmed+1, tmed} := js2$
 $M2_{i, T_1+T_2} := 0$
 $M2_{(T_1+T_2+T_3+1), T_1+T_2} := js2$
 $M2_{tap+1, tap} := js3$
 $M2_{tpp+1, tpp} := js4$
 $M2_{(T_1+T_2+T_3+T_4+1), T_1+T_2+T_3+T_4} := js4 \cdot propN2$
 $M2_{(T_1+T_2+T_3+T_4+T_5+1), T_1+T_2+T_3+T_4} := js4 \cdot propFL2$
 $M2_{(T_1+T_2+T_3+T_4+T_5+T_6+1), T_1+T_2+T_3+T_4} := js4 \cdot propG2$
 $M2_{tN+1, tN} := js5$
 $M2_{i, T_1+T_2+T_3+T_4+T_5} := 0$
 $M2_{ad1, T_1+T_2+T_3+T_4+T_5} := js5$
 $M2_{tF+1, tF} := js6$
 $M2_{i, T_1+T_2+T_3+T_4+T_5+T_6} := 0$
 $M2_{ad1, T_1+T_2+T_3+T_4+T_5+T_6} := js6$ $T_1 + T_2 + T_3 + T_4 + T_5 + T_6 = 30$ $js6 = 0.9$ $propFL2 = 0.2$
 $M2_{tG+1, tG} := js7$

$M2_{ad1, ad1} := Nadm$

rows(M2) = 39 cols(M2) = 39

$\lambda_2 := \max(\text{Re}(\text{eigenval}(M2)))$

$\lambda_2 = 0.93$

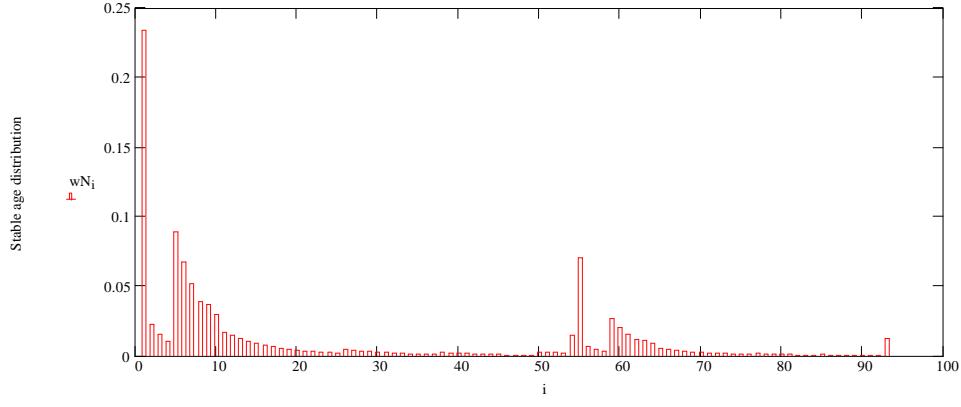
Put these two matrices together to make the Northern population matrix

```
M1zero(cols(M1), cols(M2)) := 0      M2zero(cols(M2), cols(M1)) := 0
Mrow1 := augment(M1, M1zero)      Mrow2 := augment(M2zero, M2)
NM := stack(Mrow1, Mrow2)
NMadN2+1, adN1 := FN1 · pSRNm      pSRNm = 0.3      rows(NM) = 93      cols(NM) = 93
NMadN2+1, adN2 := FN2 · pSRNm
```

NM =	82 83 84 85 86 87 88 89 90 91	λN := max(Re(eigenvals(NM)))	λN = 1.052
76	0 0 0 0 0 0 0 0 0 0		
77	0 0 0 0 0 0 0 0 0 0		
78	0 0 0 0 0 0 0 0 0 0		
79	0 0 0 0 0 0 0 0 0 0		
80	0 0 0 0 0 0 0 0 0 0		
81	0 0 0 0 0 0 0 0 0 0		
82	0 0 0 0 0 0 0 0 0 0		
83	0.9 0 0 0 0 0 0 0 0 0		
84	0 0.9 0 0 0 0 0 0 0 0		
85	0 0 0 0 0 0 0 0 0 0		
86	0 0 0 0.9 0 0 0 0 0 0		
87	0 0 0 0 0.9 0 0 0 0 0		
88	0 0 0 0 0 0.9 0 0 0 0		
89	0 0 0 0 0 0 0.9 0 0 0		
90	0 0 0 0 0 0 0 0.9 0 0		
91	0 0 0 0 0 0 0 0 0.9 0		

$$wN := \frac{\text{eigenved}(NM, \lambda N)}{\sum \text{eigenved}(NM, \lambda N)} \quad N := 1000000 \quad vN := \frac{\text{eigenved}(NM^T, \lambda N)}{\text{eigenved}(NM^T, \lambda N)_1}$$

wN	1	vN · N =	1	i := 1 .. cols(M1) + cols(M2)	j := 1 .. cols(M1) + cols(M2)	ElastN := Elast1	ElastN =
1	0.234	1	1				{ 0.034 }
2	0.022	2	2.033				0.02
3	0.015	3	2.969				0.109
4	0.01	4	4.336				0.068
5	0.089	5	2.121				0.302
6	0.068	6	2.788				0.11
7	0.052	7	3.665				0.055
8	0.039	8	4.818				
9	0.037	9	6.334				
10	0.03	10	7.836				
11	0.017	11	8.226				
12	0.014	12	9.612				
		13	11.231				0.28 }



```
femT := 1 .. cols(M1)      maleT := cols(M1) + 1 .. cols(M1) + cols(M2)
N0 := N · wN
allfem :=  $\sum_{\text{femT}} N0_{\text{femT}}$       allfem =  $7.685 \times 10^5$       allmale :=  $\sum_{\text{maleT}} N0_{\text{maleT}}$       allmale =  $2.315 \times 10^5$       allNSR :=  $\frac{\text{allmale}}{\text{allfem}}$       allNSR = 0.301
```

```
adfem :=  $\sum_{\text{tAd}} N0_{\text{tAd}} + N0_{\text{adN2}}$       adfem =  $2.38 \times 10^4$       admale :=  $N0_{\text{cols(M1)+cols(M2)}}$       admale =  $1.217 \times 10^4$       adNSR :=  $\frac{\text{admale}}{\text{adfem}}$       adNSR = 0.511
```

2.Southern nesting subpopulation primary sex ratio: pSRS := 0.85

proportion moving to "split" stages
 propMed1 := 0.2
 propNA1 := 1 - propMed1
 propFL1 := 0.5
 propG1 := 0.3
 propN1 := 1 - propFL1 - propG1

female stage lengths:

$$T := \begin{pmatrix} 1 \\ 3 \\ 4 \\ 2 \\ 15 \\ 12 \\ 12 \\ 2 \end{pmatrix}$$

post-hatchling
 Mediterranean pelagic
 Atlantic pelagic
 Transition pelagic
 Mid Atlantic benthic
 Florida benthic
 Gulf benthic
 Adult (1st remigration interval)

male stage lengths:

$$TNm := \begin{pmatrix} 1 \\ 3 \\ 4 \\ 2 \\ 12 \\ 8 \\ 8 \end{pmatrix}$$

SOuthern adult female survival Sadf := 0.93

Southern adult male survival Sadm := 0.93

reproduction - neophyte females

$$fneo := \begin{pmatrix} pSRS \\ 80 \\ 3 \\ 0.5 \\ T_8 \\ .25 \end{pmatrix}$$

sex ratio (proportion female)
 eggs per nest
 nests per female
 nest survival
 remigration
 hatchling survival to age 1

reproduction - experienced females

$$f2 := \begin{pmatrix} pSRS \\ 110 \\ 4 \\ 0.6 \\ 3 \\ .25 \end{pmatrix}$$

FS2 := $\frac{f2_1 \cdot f2_2 \cdot f2_3 \cdot f2_4}{f2_5} \cdot f2_6$

$$FS1 := ((fneo_1 \cdot fneo_2 \cdot fneo_3 \cdot fneo_4) \cdot fneo_5)$$

$$FS1 = 25.5$$

$$FS2 = 18.7$$

range variables:

$$tph := 1 .. T_1$$

$$tN := T_1 + T_2 + T_3 + T_4 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5$$

$$Tph := 1 .. T_1$$

$$tmed := T_1 + 1 .. T_1 + T_2$$

$$tap := T_1 + T_2 + 1 .. T_1 + T_2 + T_3$$

$$tF := T_1 + T_2 + T_3 + T_4 + T_5 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5 + T_6$$

$$Tmed := 1 .. T_2$$

$$q := 1 .. 7$$

$$tAd := T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8$$

$$Tap := 1 .. T_3$$

$$adS1 := \sum_q T_q + 1$$

$$adS2 := adS1 + T_8$$

$$adS1 = 50 \quad adS2 = 52$$

$$tAd =$$

$$\begin{pmatrix} 50 \\ 51 \end{pmatrix}$$

$$i := 1 .. adS2$$

matrix construction

matrix construction

$M3_{tph+1, tph} := js1$	tF = 26 27 28 29 30 31 32 33 34 35 36 37			
$M3_{(T_1+1, T_1)} := js1 \cdot propMed1$	$T_8 = 2$			
$M3_{(T_1+T_2+1), T_1} := js1 \cdot (1 - propMed1)$				
$M3_{tmed+1, tmed} := js2$				
$M3_{i, T_1+T_2} := 0$				
$M3_{(T_1+T_2+T_3+1), T_1+T_2} := js2$				
$M3_{tap+1, tap} := js3$				
$M3_{tpp+1, tpp} := js4$				
$M3_{(T_1+T_2+T_3+T_4+1), T_1+T_2+T_3+T_4} := js4 \cdot propN1$	$T_1 + T_2 + T_3 + T_4 + T_5 = 25$			
$M3_{(T_1+T_2+T_3+T_4+T_5+1), T_1+T_2+T_3+T_4} := js4 \cdot propFL1$				
$M3_{(T_1+T_2+T_3+T_4+T_5+T_6+1), T_1+T_2+T_3+T_4} := js4 \cdot propG1$				
$M3_{tN+1, tN} := js5$				
$M3_{i, T_1+T_2+T_3+T_4+T_5} := 0$				
$M3_{adS1, T_1+T_2+T_3+T_4+T_5} := js5$				
$M3_{tF+1, tF} := js6$				
$M3_{i, T_1+T_2+T_3+T_4+T_5+T_6} := 0$				
$M3_{adS1, T_1+T_2+T_3+T_4+T_5+T_6} := js6$	$T_1 + T_2 + T_3 + T_4 + T_5 + T_6 = 37$	$js6 = 0.9$	$propFL1 = 0.5$	
$M3_{tG+1, tG} := js7$				
$M3_{adS1, adS1-1} := js7$				
$M3_{tAd+1, tAd} := Sadf$	$M3_{1, adS1} := FS1$			
$M3_{1, adS2} := FS2$	$M3_{adS2, adS2} := Sadf$	$adS1 = 50$	$rows(M3) = 52$	$cols(M3) = 52$
$\lambda_3 := \max(\text{Re}(\text{eigenval}(M3)))$	$\lambda_3 = 1.081$			

$$w := \frac{\text{eigenv}(M3, \lambda_3)}{\sum \text{eigenv}(M3, \lambda_3)} \quad N := 1000000 \quad v := \frac{\text{eigenv}(M3^T, \lambda_3)}{\sum \text{eigenv}(M3^T, \lambda_3)}$$

	1
1	337890.58
2	31256.28
3	20817.62
4	13865.16
5	125025.13
6	92522.76
7	68469.92
8	50670.02
9	46732.11
10	36744.77
11	5778.37
12	4810.71
13	4005.1
14	3334.39
15	2776.01
16	2311.13
17	1924.1
18	1601.89
19	1333.63
20	1110.3
21	924.36

	1
1	1
2	2.136
3	3.207
4	4.816
5	2.169
6	2.93
7	3.96
8	5.351
9	7.23
10	9.196
11	7.372
12	8.855
13	10.636
14	12.776
15	15.346
16	18.432
17	22.14

j := 1 .. adS2

i := 1 .. adS2

$$E_{i,j} := \frac{v_i w_j}{v \cdot w} \frac{M3_{i,j}}{\lambda_3}$$

$$\sum_i \sum_j E_{i,j} = 1$$

	1
1	0
2	0.00741
3	0.00
4	0
5	0.03009
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0
32	0
33	0
34	0
35	0

	tN =
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23
24	24
25	25

$$\text{Elast2} := \begin{bmatrix} \sum_{\text{tph}} \left(\sum_i E_{\text{eph},i} \right) \\ \sum_{\text{tmel}} \left(\sum_i E_{\text{med},i} \right) \\ \sum_{\text{tap}} \left(\sum_i E_{\text{ap},i} \right) \\ \sum_{\text{tp}} \left(\sum_i E_{\text{tp},i} \right) \\ \sum_{\text{tN}} \left(\sum_i E_{\text{tN},i} \right) \\ \sum_{\text{tF}} \left(\sum_i E_{\text{tF},i} \right) \\ \sum_{\text{tG}} \left(\sum_i E_{\text{tG},i} \right) \\ \sum_{\text{tAd}} \left(\sum_i E_{\text{tAd},i} \right) + E_{\text{adN2}, \text{adN2}} \end{bmatrix} \quad \text{Elast2} = \begin{bmatrix} 0.037 \\ 0.022 \\ 0.12 \\ 0.075 \\ 0.071 \\ 0.246 \\ 0.147 \\ 0.244 \end{bmatrix}$$

tAd =

50

51

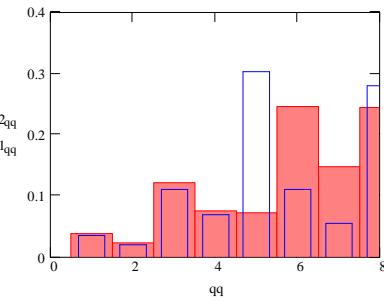
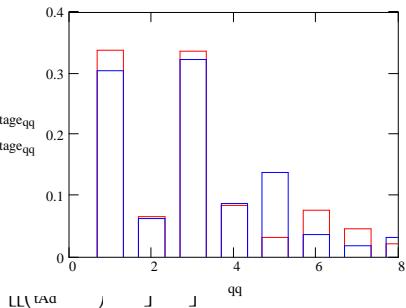
wtmed =

0.031
0.021
0.014

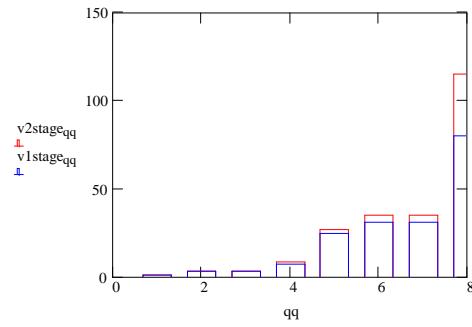
wtap =

0.125
0.093
0.068
0.051

$$\sum_{\text{tmel}} (w_{\text{tmel}}) = 0.066 \quad \sum_{\text{tap}} (w_{\text{tap}}) = 0.337$$



1	post-hatching
3.207	Mediterranean pelagic
3.406	Atlantic pelagic
8.154	Transition pelagic
26.593	Mid Atlantic benthic
35.008	Florida benthic
35.008	Gulf benthic
114.968	Adult



post-hatching
Mediterranean pelagic
Atlantic pelagic
Transition pelagic
Mid Atlantic benthic
Florida benthic
Gulf benthic
Adult

Southern nesting subpopulation - males
 sex ratio: $pSRS_m := 1 - pSRS$ $pSRS_m = 0.15$
 stage lengths:
 post-hatching proportion moving to "split" stages
 Mediterranean pelagic $propMed2 := propMed1$
 Atlantic pelagic $propNA2 := 1 - propMed2$
 $T := TN_m$ $propFL2 := propFL1$
 Transition pelagic $propG2 := propG1$
 Mid Atlantic benthic $propN2 := 1 - propFL2 - propG2$
 Florida benthic
 Gulf benthic

range variables:
 $tph := 1 .. T_1$ $tN := T_1 + T_2 + T_3 + T_4 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5$
 $tmed := T_1 + 1 .. T_1 + T_2$
 $tap := T_1 + T_2 + 1 .. T_1 + T_2 + T_3$ $tF := T_1 + T_2 + T_3 + T_4 + T_5 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5 + T_6$
 $ttp := T_1 + T_2 + T_3 + 1 .. T_1 + T_2 + T_3 + T_4$ $tG := T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + 1 .. T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7$
 $q := 1 .. 7$

$ad1 := \sum_q T_q + 1$ $ad1 = 39$
 $i := 1 .. ad1$

matrix construction

$M4_{tph+1, tph} := js_1$	$tF =$		
$M4_{(T_1+1, T_1)} := js_1 \cdot propMed2$	23		
$M4_{(T_1+T_2+1), T_1} := js_1 \cdot (1 - propMed2)$	24		
$M4_{tmed+1, tmed} := js_2$	25		
$M4_{i, T_1+T_2} := 0$	26		
$M4_{(T_1+T_2+T_3+1), T_1+T_2} := js_2$	27		
$M4_{tap+1, tap} := js_3$	28		
$M4_{ttp+1, ttp} := js_4$	29		
$M4_{(T_1+T_2+T_3+T_4+1), T_1+T_2+T_3+T_4} := js_4 \cdot propN2$	30		
$M4_{(T_1+T_2+T_3+T_4+T_5+1), T_1+T_2+T_3+T_4} := js_4 \cdot propFL2$			
$M4_{(T_1+T_2+T_3+T_4+T_5+T_6+1), T_1+T_2+T_3+T_4} := js_4 \cdot propG2$			
$M4_{tN+1, tN} := js_5$			
$M4_{i, T_1+T_2+T_3+T_4+T_5} := 0$			
$M4_{ad1, T_1+T_2+T_3+T_4+T_5} := js_5$			
$M4_{tF+1, tF} := js_6$			
$M4_{i, T_1+T_2+T_3+T_4+T_5+T_6} := 0$			
$M4_{ad1, T_1+T_2+T_3+T_4+T_5+T_6} := js_6$	$T_1 + T_2 + T_3 + T_4 + T_5 + T_6 = 30$	$js_6 = 0.9$	$propFL2 = 0.5$
$M4_{tG+1, tG} := js_7$			
$M4_{ad1, ad1} := Sadm$			

rows(M4) = 39 cols(M4) = 39

$\lambda_4 := \max(\text{Re}(\text{eigenval}(M4)))$

Put these two matrices together to make the Southern population matrix

```
M3zerocols(M3), cols(M4) := 0      M4zerocols(M4), cols(M3) := 0
Mrow1 := augmen(M3, M3zero)      Mrow2 := augmen(M4zero, M4)
SM := stack(Mrow1, Mrow2)
SMadS2+1, adS1 := FS1·pSRSm      pSRSm = 0.15      rows(SM) = 91      cols(SM) = 91
SMadS2+1, adS2 := FS2·pSRSm
```

	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0.1	0	0	0	0	0	0	0	0	0
3	0	0.72	0	0	0	0	0	0	0	0
4	0	0	0.72	0	0	0	0	0	0	0
5	0.4	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0.8	0	0	0	0	0
7	0	0	0	0	0	0.8	0	0	0	0
8	0	0	0	0	0	0	0.8	0	0	0
9	0	0	0	0.72	0	0	0	0.8	0	0
10	0	0	0	0	0	0	0	0	0.85	0
11	0	0	0	0	0	0	0	0	0	0.17
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0

$$wS := \frac{\text{eigenved}(SM, \lambda S)}{\sum \text{eigenved}(SM, \lambda S)} \quad N := 1000000 \quad vS := \frac{\text{eigenved}(SM^T, \lambda S)}{\text{eigenved}(SM^T, \lambda S)_1}$$

	1
1	0.294
2	0.027
3	0.018
4	0.012
5	0.109
6	0.08
7	0.06
8	0.044
9	0.041
10	0.032
11	5.022·10 ⁻³
12	4.181·10 ⁻³

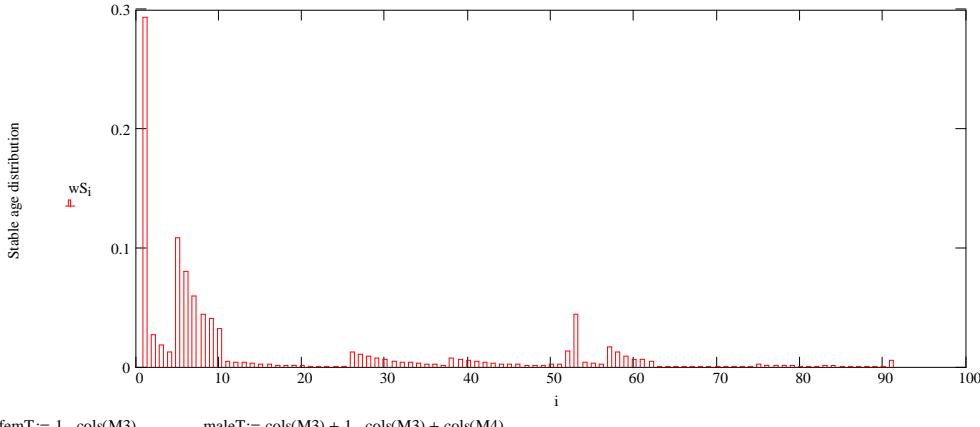
	1
1	293679.65
2	27166.59
3	18093.76
4	12050.99
5	108666.35
6	80416.71
7	59511.04
8	44040.15
9	40617.49
10	31936.94
11	5022.31

	1
1	1
2	2.136
3	3.207
4	4.816
5	2.169
6	2.93
7	3.96
8	5.351
9	7.23
10	9.196
11	7.372
12	8.855
13	10.636

$$i := 1.. \text{cols}(M1) + \text{cols}(M2)$$

$$j := 1.. \text{cols}(M1) + \text{cols}(M2)$$

$$\text{ElastS} := \begin{pmatrix} 0.037 \\ 0.022 \\ 0.12 \\ 0.075 \\ 0.071 \\ 0.246 \\ 0.147 \\ 0.244 \end{pmatrix}$$



femT := 1 .. cols(M3) maleT := cols(M3) + 1 .. cols(M3) + cols(M4)

N0 := N·wS

$$\text{allfem} := \sum_{\text{femT}} \text{N0femT} \quad \text{allfem} = 8.692 \times 10^5 \quad \text{allmale} := \sum_{\text{maleT}} \text{N0maleT} \quad \text{allmale} = 1.308 \times 10^5 \quad \text{allSSR} := \frac{\text{allmale}}{\text{allfem}} \quad \text{allSSR} = 0.151$$

$$\text{adfem} := \sum_{\text{tAd}} \text{N0tAd} + \text{N0adS2} \quad \text{adfem} = 1.824 \times 10^4 \quad \text{admale} := \text{N0cols}(M3) + \text{cols}(M4) \quad \text{admale} = 5.576 \times 10^3 \quad \text{adSSR} := \frac{\text{admale}}{\text{adfem}} \quad \text{adSSR} = 0.306$$

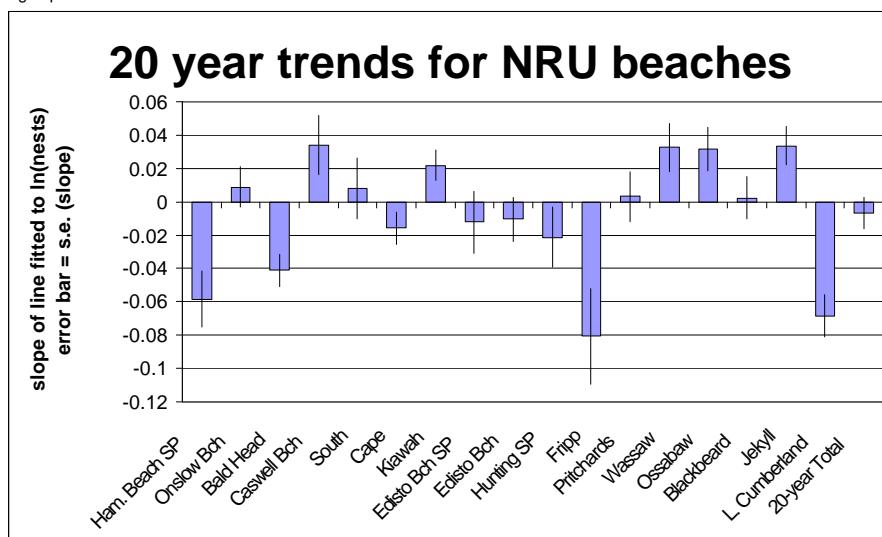
Analysis of abundance trends and sex ratio contribution for Loggerhead Reproductive Units

Initial analysis of laparoscopy data from the Wyneken-Crowder study suggests highly variable sex ratios for different beaches and among years. In general, there is less difference in the primary sex ratio on northern vs. southern beaches than expected. However, there is a strong females bias for nearly all beaches in both years. Data analysis is still underway.

The next step is to determine the relative contribution of different nesting beaches to total hatchling production for each sex, and to examine the trends in different nesting beaches over time. This will allow us to generate a qualitative time series of expected changes in sex ratio. Working with the Loggerhead Recovery Team and Florida nesting data available on the web, I examined trends in nest numbers for the Northern Recovery Unit (NRU – data supplied by Mark Dodd, GA DNR) and for Florida counties (<http://floridamarine.org>). I also weighted the trends according to the contribution of each beach to each year's total, to see which trends were contributing most to the total population trend. In general, the NRU has been declining slightly over a 20 year period, driven strongly by recent declines in the number of nests counted at Cape Island, SC. Florida nests have generally increased since 1989, although recent years suggest stable or declining populations. The trends generated by the county nest totals are comparable to those of index beaches; the totals shown here will be used to estimate relative contributions of hatchlings over time (nests multiplied by mean egg survival). The largest contributions have been from Brevard and Palm Beach counties.

Currently, we are gathering data from index beaches on the egg survival rate and nest incubation durations to estimate the number of male and female hatchlings produced.

Northern reproductive unit - corrected data from Loggerhead Recovery Team



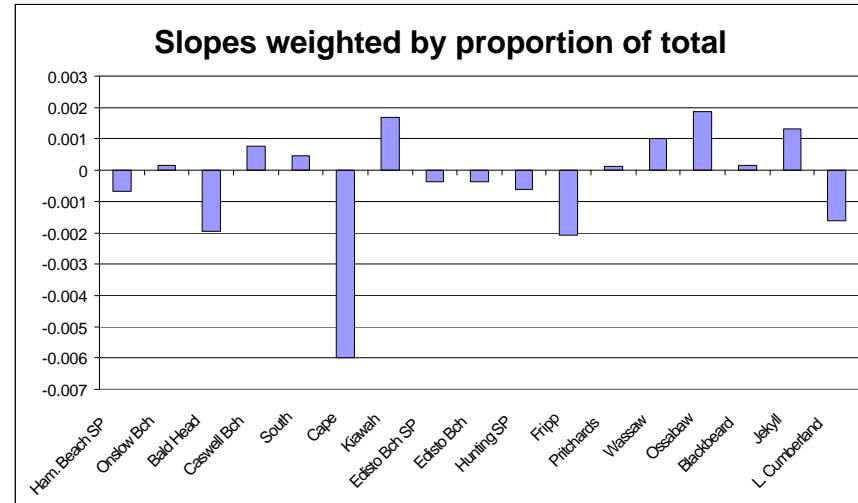
Proportion of total by year

	Ham. Beach SP	Bald Head	Caswell Bch	South	Cape	Kiawah	Edisto Bch SP	Edisto Bch	Hunting SP	Fripp	Pritchards	Wassaw	Ossabaw	Blackbear d	Jekyll	Cumberla nd	L. Total	20-year Total
1983	0.017299	0.020182605	0.07112	0.017299	0.049976	0.320519	0.063431	0.023546	0.04469	0.045651	0.059587	0.043729	0.029313	0.054781	0.060548	0.02691	0.051418	1
1984	0.008802	0.021327014	0.042654	0.003724	0.045701	0.414353	0.057211	0.040961	0.032837	0.053148	0.038253	0.034868	0.024035	0.037238	0.067366	0.042316	0.035206	1
1985	0.021665	0.012744265	0.056075	0.026338	0.046304	0.338148	0.057774	0.029312	0.033985	0.037383	0.074766	0.029312	0.028037	0.048428	0.078165	0.028462	0.053101	1
1986	0.015911	0.010832769	0.066012	0.013879	0.02979	0.427894	0.05958	0.038592	0.034868	0.013879	0.058226	0.038253	0.016249	0.033852	0.079215	0.026066	0.036899	1
1987	0.016243	0.012994044	0.050893	0.021115	0.031402	0.44667	0.084461	0.029237	0.024905	0.012453	0.034109	0.030861	0.012453	0.061722	0.059556	0.041689	0.029237	1
1988	0.007556	0.015555556	0.049778	0.020889	0.068444	0.421333	0.069333	0.024889	0.038667	0.013778	0.036444	0.078222	0.019111	0.024889	0.053333	0.034222	0.023556	1
1989	0.016648	0.016648169	0.059933	0.015538	0.051054	0.433962	0.046615	0.014428	0.028302	0.031632	0.028302	0.057159	0.022752	0.04606	0.083241	0.022198	0.025527	1
1990	0.011155	0.013566476	0.054869	0.02442	0.070546	0.410311	0.068737	0.038589	0.030449	0.028037	0.026831	0.052457	0.01839	0.042508	0.065421	0.022309	0.021405	1
1991	0.014961	0.014960898	0.061544	0.023801	0.057803	0.360762	0.068344	0.039442	0.043863	0.027202	0.021761	0.041142	0.034002	0.061544	0.070724	0.029922	0.028222	1
1992	0.016073	0.007654038	0.052047	0.026024	0.065825	0.404899	0.068121	0.039801	0.028703	0.049751	0.010333	0.045159	0.035591	0.050517	0.057405	0.028703	0.013395	1
1993	0.012077	0.025764895	0.057166	0.015298	0.026567	0.466184	0.080515	0.019324	0.030596	0.041868	0.006441	0.033011	0.02818	0.047504	0.045089	0.033816	0.030596	1
1994	0.010652	0.018483709	0.037594	0.031328	0.083647	0.384712	0.067356	0.046679	0.036654	0.035401	0.00282	0.02099	0.032581	0.06015	0.08302	0.030702	0.017231	1
1995	0.005769	0.0125	0.042308	0.016827	0.062019	0.436058	0.067788	0.016827	0.023558	0.041827	0.009135	0.054327	0.037981	0.060096	0.058654	0.037981	0.016346	1
1996	0.009037	0.02043222	0.0389	0.027505	0.090766	0.340275	0.082122	0.033006	0.031827	0.021611	0.012181	0.055796	0.054224	0.069155	0.067976	0.035363	0.009823	1
1997	0.010989	0.012281836	0.048481	0.032321	0.078862	0.32256	0.107951	0.031674	0.029735	0.023271	0.005171	0.03426	0.038785	0.069166	0.082094	0.056238	0.01616	1
1998	0.003281	0.01804758	0.036095	0.018868	0.093929	0.339623	0.087367	0.022149	0.027892	0.022559	0.027892	0.069319	0.028302	0.073011	0.073011	0.04799	0.010664	1
1999	0.016112	0.014711033	0.037478	0.030123	0.058144	0.328546	0.091769	0.022067	0.047986	0.019264	0.014011	0.046935	0.043783	0.103327	0.067601	0.047636	0.010508	1
2000	0.009645	0.020812183	0.022335	0.027919	0.063452	0.312183	0.122843	0.027411	0.024873	0.017259	0.018782	0.054315	0.041624	0.094924	0.073604	0.047208	0.020812	1
2001	0.005409	0.027644231	0.046274	0.035457	0.05649	0.322115	0.096755	0.026442	0.040264	0.025841	0.025841	0.039063	0.045072	0.061298	0.08113	0.052284	0.01262	1
2002	0.007289	0.019134396	0.032802	0.018223	0.040547	0.4	0.087016	0.027335	0.042825	0.022323	0.010934	0.042825	0.025513	0.070159	0.080638	0.05877	0.013667	1
2003	0.003922	0.020392157	0.030196	0.029412	0.038824	0.328235	0.089412	0.034118	0.024706	0.026275	0.021176	0.048627	0.045098	0.07451	0.083137	0.08	0.021961	1

average 0.011452 0.016984289 0.04736 0.022681 0.057624 0.379016 0.077357 0.029801 0.033437 0.029067 0.025857 0.045268 0.03148 0.059278 0.070044 0.039561 0.023731

slope weighted by average contribution

-0.00067 0.000149532 -0.00194 0.00077 0.000472 -0.00598 0.001686 -0.00036 -0.00035 -0.00062 -0.00208 0.000139 0.001027 0.001881 0.000166 0.001329 -0.00163

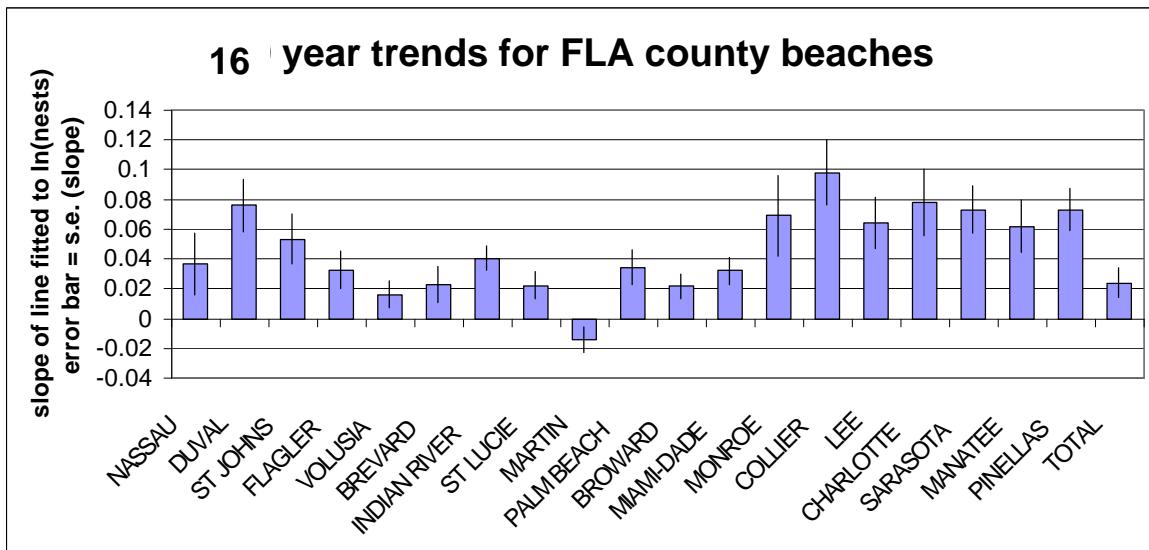


FLA county trends

are these technically in the NRU?

Proportion of total by year

alpha=5% 4.6
alpha=10% 3.25



Proportion of total by year

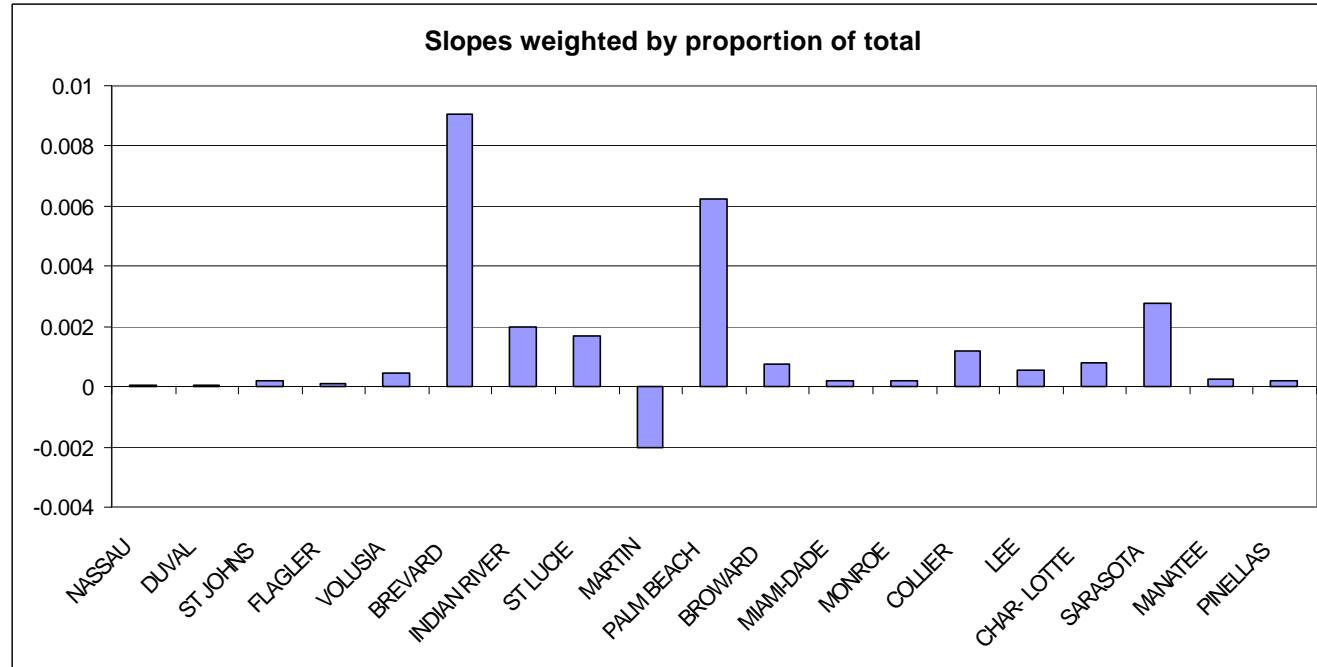
alpha=10%

	NASSAU	DUVAL	ST JOHNS	FLAGLER	VOLUSIA	BREVARD	INDIAN RIVER	ST LUCIE	MARTIN	PALM BEACH	BROWARD	MIAMI-DADE	MONROE	COLLIER	LEE	CHAR-LOTTE	SARASOTA	MANATEE	PINELLAS
1988	0.001615	0.00157719	0.00245	0.00442421	0.03605083	0.35488127	0.052151	0.087125	0.220317	0.150046	0.03632007	0.005896	0.0034732	0.0074309	0.00595	0.004496258	0.0022535135	0.0021539	0.00150773
1989	0.001015	0.000405935	0.003146	0.0043638	0.02908523	0.39759281	0.048367	0.077432	0.190931	0.158923	0.03635146	0.006596	0.0012178	0.0035722	0.004039	0.007915728	0.023503623	0.00367371	0.0018673
1990	0.001278	0.000646646	0.005459	0.00515813	0.02655759	0.41615411	0.036468	0.073853	0.159797	0.186384	0.03433238	0.005865	0.0027069	0.0061206	0.007188	0.005353625	0.021820533	0.00269185	0.00216551
1991	0.001697	0.000585257	0.002283	0.00277997	0.02515144	0.41376233	0.049762	0.075293	0.15799	0.174392	0.02974571	0.006423	0.0019313	0.008852	0.008179	0.007066983	0.028911714	0.00263366	0.0025605
1992	0.001269	0.000448896	0.003266	0.00275529	0.02255313	0.39556987	0.043125	0.077102	0.125304	0.222234	0.03451852	0.005681	0.0017027	0.0086683	0.006935	0.007615745	0.036283145	0.00277077	0.00219804
1993	0.000598	0.000543183	0.002444	0.00333152	0.03181242	0.3729857	0.050552	0.078309	0.169763	0.170632	0.04104653	0.007098	0.0019917	0.010067	0.008818	0.009741083	0.034691291	0.00367554	0.00190114
1994	0.00155	0.001099366	0.004228	0.00422833	0.03003524	0.39505285	0.042903	0.069542	0.158675	0.177674	0.03072586	0.006272	0.0024101	0.0160958	0.009739	0.008766737	0.035842142	0.00321353	0.00194503
1995	0.000753	0.000677286	0.003324	0.00338643	0.02563652	0.39700238	0.043497	0.072896	0.145566	0.177135	0.03219616	0.005895	0.0052803	0.0132949	0.00878	0.013445378	0.043923241	0.00443998	0.00287219
1996	0.001386	0.000911011	0.002693	0.0029971	0.02494059	0.37948244	0.048125	0.081819	0.122841	0.201796	0.03831529	0.005915	0.0039609	0.0151571	0.009057	0.013203063	0.040454185	0.00400053	0.00294428
1997	0.001186	0.000982833	0.003307	0.00273011	0.01985959	0.39346334	0.05259	0.07156	0.123151	0.180842	0.03457098	0.006474	0.0051638	0.0172231	0.009267	0.016396256	0.053634945	0.00477379	0.00282371
1998	0.001322	0.000849758	0.004249	0.00318659	0.02452496	0.40830875	0.053004	0.077906	0.120076	0.165892	0.0311932	0.006432	0.004119	0.0159566	0.010209	0.016393249	0.048931901	0.00469727	0.00274991
1999	0.001858	0.001494111	0.00344	0.00297567	0.02841323	0.42857143	0.045087	0.073626	0.117771	0.165507	0.03244356	0.006479	0.0038922	0.01582	0.010685	0.012668558	0.041634231	0.00547422	0.00215956
2000	0.001261	0.000961099	0.0034	0.00403662	0.02652635	0.39537231	0.061318	0.079123	0.124006	0.170439	0.03212475	0.006199	0.0041688	0.0163027	0.011233	0.013094981	0.042792955	0.00428891	0.00335183
2001	0.001294	0.001264811	0.003954	0.00404158	0.02440939	0.38086792	0.049139	0.08214	0.119314	0.2	0.03374282	0.007211	0.0039253	0.0138693	0.009595	0.011266991	0.046681689	0.00444864	0.00283492
2002	0.000981	0.000884458	0.005033	0.00543539	0.02989467	0.3777759	0.058664	0.081225	0.110155	0.209568	0.03328777	0.006014	0.001592	0.0118357	0.009005	0.010549168	0.041553429	0.00289459	0.0036504
2003	0.002269	0.001406447	0.005338	0.00564177	0.02732983	0.36749828	0.060285	0.070386	0.11071	0.207179	0.0373188	0.007815	0.0048107	0.0183318	0.009861	0.009541466	0.044974348	0.00476274	0.00453899

average 0.001333 0.000849426 0.003626 0.00384317 0.02704881 0.39214636 0.04969 0.076834 0.142273 0.182415 0.03426462 0.006392 0.0032717 0.0124124 0.008659 0.010469704 0.038010532 0.0037871 0.00262944

slope weighted by average contribution

4.86E-05 6.81033E-05 0.000193 0.00012569 0.00043939 0.00904044 0.001998 0.00171 -0.00203 0.006231 0.00074225 0.000204 0.0002264 0.0012176 0.000559 0.000816417 0.002779361 0.00023413 0.00019235



Correlations (uncorrected)

	NASSAU	DUVAL	ST.JOHNS	FLAGLER	VOLUSIA	BREVARD	DIAN RIVE	ST.LUCIE	MARTIN	ALM BEAC	BROWARD	MIAMI-DADI	MONROE	COLLIER	LEE	CHARLOTTE	SARASOTA	MANATEE	PINELLAS	TOTAL
NASSAU	1																			
DUVAL	0.763896	1																		
ST.JOHNS	0.488167	0.535645335	1																	
FLAGLER	0.344013	0.432834874	0.851222	1																
VOLUSIA	0.48494	0.602956518	0.564822	0.54992654	1															
BREVARD	0.579191	0.55487843	0.616484	0.35954225	0.7729888	1														
INDIAN RIVER	0.511066	0.58515742	0.521473	0.46295734	0.63721912	0.727792	1													
ST.LUCIE	0.469625	0.534638295	0.546461	0.36623726	0.74674392	0.91836513	0.819736	1												
MARTIN	0.061846	-0.057174806	0.083961	0.04837143	0.52655363	0.52434111	0.094448	0.378966	1											
PALM BEACH	0.51592	0.492506255	0.663759	0.46333181	0.57228998	0.81256889	0.690883	0.85042	0.14414	1										
BROWARD	0.452761	0.528969702	0.536336	0.35756632	0.67222508	0.83156848	0.725763	0.876418	0.282414	0.858653	1									
MIAMI-DADE	0.656212	0.711285881	0.644816	0.46248446	0.71488024	0.86501465	0.824652	0.834229	0.283125	0.782007	0.8399457	1								
MONROE	0.443055	0.659875625	0.458649	0.28799088	0.46605597	0.6687473	0.66964	0.669426	0.214717	0.576102	0.7151527	0.731429	1							
COLLIER	0.635174	0.818593345	0.56178	0.38615579	0.66509326	0.74907194	0.841733	0.761181	0.127651	0.713033	0.77758435	0.861062	0.8312602	1						
LEE	0.620589	0.765783052	0.613703	0.44803048	0.81076759	0.8832797	0.880594	0.890737	0.294178	0.776365	0.83392406	0.917594	0.7638245	0.9349563	1					
CHARLOTTE	0.348541	0.57380829	0.445913	0.18580334	0.56261333	0.78454304	0.812944	0.826866	0.207313	0.656188	0.79625977	0.78936	0.8335739	0.8679233	0.846223	1				
SARASOTA	0.453781	0.670186266	0.549982	0.29435113	0.55462961	0.78041589	0.846203	0.821745	0.079871	0.773211	0.79832783	0.858443	0.8356369	0.9275876	0.892765	0.949869046	1			
MANATEE	0.548766	0.75857654	0.511528	0.28328216	0.64014911	0.80634936	0.756104	0.774814	0.202001	0.641928	0.81499053	0.885406	0.8648901	0.875969	0.864331	0.904647224	0.89703952	1		
PINELLAS	0.51729	0.556910254	0.648146	0.63332816	0.50685397	0.62269666	0.882656	0.706498	-0.06138	0.775612	0.71466927	0.770108	0.699098	0.7692671	0.757619	0.678714786	0.781272618	0.66999584	1	
TOTAL	0.563747	0.583737223	0.636397	0.41294714	0.78284877	0.98273896	0.797145	0.95332	0.463889	0.872929	0.88898149	0.900135	0.7230282	0.8190946	0.925342	0.829808761	0.846382516	0.82856486	0.71858425	1